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Virtual Realism and Clinical Readiness: Evaluating High-Fidelity Simulation in Road Traffic Accident Management Training

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ABSTRACT

Objectives: Limited clinical exposure during undergraduate nursing education may hinder the effective application of theoretical knowledge in emergencies such as road traffic accident (RTA) management. Simulation-based education (SBE) offers a structured approach to support the development of clinical skills in a safe learning environment. The study aims to evaluate the effectiveness of a high-fidelity simulation (HFS)-based teaching module in enhancing the application of knowledge into clinical skills for RTA management among undergraduate nursing students.

Material and Methods: A quasi-experimental pretest-posttest study was conducted among 90 undergraduate nursing students from a nursing college in India. Participants underwent a structured HFS intervention incorporating pre-briefing, scenario-based training, and guided debriefing. Perception, knowledge, and clinical skill outcomes were assessed using validated instruments. Data were analysed using descriptive and inferential statistics, including paired and independent t-tests and Pearson's correlation analysis.

Results: Following the simulation intervention, a statistically significant improvement in clinical skill performance was observed (p <0.001). Knowledge and perception scores also increased; however, knowledge gain was not emphasised as a primary outcome. Correlation analysis demonstrated a significant positive relationship between knowledge and skill scores (r = 0.368, p = 0.001), indicating effective translation of theoretical understanding into clinical performance. Cohort-wise comparisons showed differential responsiveness, with greater skill improvement among students in earlier stages of training.

Conclusion: HFS was associated with improved clinical skill performance and supported the application of knowledge in emergency care. Early integration of structured simulation experiences within undergraduate nursing curricula may strengthen clinical readiness, while progressive simulation complexity may be required to sustain learning outcomes at advanced academic levels.

Keywords: Clinical skills, Emergency management, High-fidelity simulation, Nursing education, Road traffic accidents

INTRODUCTION

Integrating theoretical instruction with practical clinical experience is a fundamental requirement in nursing education to ensure safe and competent patient care. However, opportunities for direct clinical exposure are often constrained by ethical considerations, patient safety concerns, and variability in clinical postings. As a result, nursing students may encounter difficulties in applying theoretical knowledge to real-life situations, particularly during emergencies that demand rapid decision-making, prioritisation, and teamwork. These challenges can lead to gaps in clinical reasoning, psychomotor performance, and confidence when managing critical conditions such as trauma-related emergencies.[1,2]

Simulation-based education (SBE) has emerged as an effective instructional approach to address these limitations by providing a structured and controlled learning environment. Through simulation, students can practice clinical decision-making and procedural skills without risk to patients. Among various simulation modalities, high-fidelity simulation (HFS) offers enhanced realism by integrating physiological responses, interactive scenarios, and guided feedback, thereby supporting the development of critical thinking, communication, and psychomotor skills.[3-6] Despite these advantages, the role of simulation in complementing traditional clinical training continues to be examined, particularly regarding its effectiveness in promoting the application of knowledge into clinical performance.[7]

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Road traffic accidents (RTAs) remain a major global public health concern, accounting for ~1.3 million deaths and millions of non-fatal injuries annually.[8] Effective early management of trauma victims is crucial in reducing morbidity and mortality. Nevertheless, undergraduate nursing students often have limited exposure to acute trauma care during clinical training, which may affect their preparedness to manage such emergencies independently and competently.[9,10] Structured simulation experiences may help bridge this gap by allowing repeated practice of systematic assessment, prioritisation, and emergency interventions.

Although several international studies have reported positive outcomes of simulation-based training in emergency care, evidence from the Indian nursing education context remains limited, particularly regarding how simulation facilitates the translation of knowledge into clinical skills. Furthermore, few studies have examined the effectiveness of structured HFS modules across different levels of undergraduate nursing education. Addressing this gap is important for guiding curriculum design and optimising the integration of simulation-based teaching strategies to strengthen clinical readiness among nursing students.

Novelty of the study

This study adds to the limited Indian nursing education literature by examining the effectiveness of a structured HFS module in facilitating the translation of theoretical knowledge into clinical skills for RTA management. Rather than emphasising knowledge gain alone, the study focuses on how simulation supports practical skill acquisition and clinical decision-making in emergency care.

A key contribution of this study lies in its use of a standardised, scenario-based simulation design aligned with best practice guidelines, incorporating pre-briefing, immersive simulation, and guided debriefing. The integration of a human patient simulator with virtual reality elements enhanced contextual realism and provided a consistent learning experience across participants.

Additionally, by exploring learner responsiveness across different undergraduate nursing cohorts, the study offers insights into how the timing of simulation exposure within the curriculum may influence skill development. These findings inform curriculum planning by highlighting the potential value of early, structured simulation experiences and the need for progressive complexity in simulation-based training as students advance academically.

MATERIAL AND METHODS

Study design

A quasi-experimental pretest-posttest design was employed to evaluate the effectiveness of an HFS-based teaching module on the application of knowledge and development of clinical skills in RTA management among undergraduate nursing students.

Study setting and participants

The study was conducted at the Simulation Centre of Yenepoya Medical College Hospital, Mangaluru, India, after obtaining ethical approval from the Yenepoya Ethics Committee (Ref. No. YEC2/1123). A total of 90 undergraduate nursing students were recruited using purposive sampling. The sample comprised two academic cohorts: a 2nd year cohort (n = 45) and a 4th year cohort (n = 45). Students who had prior exposure to emergency simulation training or who were enrolled in the Post Basic B.Sc. Nursing programme during the period of data collection were excluded to ensure homogeneity of the sample. Written informed consent was obtained from all participants, and confidentiality and voluntary participation were maintained throughout the study.

Simulation intervention

The simulation scenario was developed in accordance with the INACSL Standards of Best Practice: Simulation Design and was reviewed and validated by experts in nursing education, emergency medicine, and simulation. The scenario depicted the emergency management of a 52-year-old male victim of an RTA presenting with airway compromise, scalp laceration, and an open fracture of the lower limb.

HFS was delivered using a human patient simulator integrated with virtual reality elements to enhance contextual realism, including simulated environmental noise, patient responses, and dynamic vital sign changes.

Each simulation session followed a structured three-phase approach. The pre-briefing phase oriented participants to the learning objectives, simulation environment, and ground rules to promote psychological safety. During the simulation phase, participants managed a 10-minute RTA scenario focusing on systematic assessment, prioritisation, hemorrhage control, immobilisation, and preparation for transfer. The session concluded with a 20-minute guided debriefing based on the Gather–Analyse–Summarise (GAS) model to facilitate reflection and clinical reasoning.

Data collection procedure

Baseline (pre-intervention) assessment of knowledge, perception, and skill was conducted prior to the simulation. Following the HFS intervention and a reinforcement

Table 1: Effect of high-fidelity simulation on perception, knowledge, and skill scores among nursing students ($n = 90$)

Outcome variable	Pre-intervention Mean ± SD	Post-intervention Mean ± SD	*t* value	*p* value
Perception score	34.06 ± 3.23	37.74 ± 4.01	6.21	<0.001*
Knowledge score	4.63 ± 1.24	6.23 ± 1.52	7.18	<0.001*
Skill score	4.53 ± 0.87	9.26 ± 3.84	18.94	<0.001*

Values are expressed as Mean ± SD. Higher scores indicate better performance. *Statistical significance set at $p < 0.05$. SD: Standard deviation.

demonstration, post-intervention assessments were carried out after 7 days using the same instruments.

Statistical analysis

Data were analysed using SPSS version 25. Descriptive statistics were used to summarise participant characteristics and outcome variables. The normality of outcome variables was assessed using the Shapiro–Wilk test and visual inspection of Q-Q plots, which supported the use of parametric statistical tests.

Paired t-tests were used to examine pre- and post-intervention differences, while independent t-tests were applied for cohort-wise comparisons as secondary analyses. Pearson's correlation coefficient was employed to assess relationships among perception, knowledge, and skill scores. Statistical significance was set at $p < 0.05$. Effect sizes were interpreted cautiously in view of the pretest-posttest design and absence of a control group.

RESULTS

Description of the participants based on demographic characteristics

The data indicate that in both the 2nd year and 4th year, the majority of participants (60.0%) were ≥21 years. Similarly, a large proportion of participants in both groups were female, with 77.8% in the 2nd year and 82.2% in the 4th year. All participants in both classes had received information on RTAs. The majority of participants in both classes (60.0%) in the 2nd year and (68.9%) in the 4th year obtained this information from healthcare professionals.

Table 1 demonstrates a statistically significant improvement in perception, knowledge, and skill scores among nursing students following the HFS intervention ($p < 0.001$). While gains were observed across all domains, the increase in skill scores was more pronounced, indicating effective translation of theoretical knowledge into clinical performance. These findings suggest that the simulation-based teaching module was particularly effective in enhancing practical emergency management skills rather than knowledge acquisition alone.

Table 2 shows a statistically significant difference in post-intervention skill scores between the two nursing student cohorts ($p < 0.001$). The 2nd year cohort achieved higher mean skill scores compared to the 4th year cohort, indicating greater responsiveness to the simulation-based teaching module. This finding suggests that earlier exposure to HFS may be more effective in strengthening clinical skill acquisition.

Table 3 illustrates the relationship between perception, knowledge, and skill scores among nursing students. A statistically significant positive correlation was observed between knowledge and skill scores ($r = 0.368$, $p = 0.001$), indicating that higher knowledge levels were associated with better clinical skill performance. In contrast, perception showed a positive but non-significant relationship with both knowledge and skill scores, suggesting that while favourable perception toward simulation may enhance engagement, it does not directly translate into measurable performance outcomes.

DISCUSSION

The present study examined the effectiveness of an HFS-based teaching module in enhancing nursing students' clinical competence in managing RTA emergencies. The findings indicate that the simulation intervention was associated with a meaningful improvement in clinical skill performance, supported by improved application of knowledge. Although knowledge scores increased following the intervention, knowledge gain was not considered the primary outcome;

Table 2: Comparison of post-intervention skill scores between nursing student cohorts

Cohort (*n*)	Mean ± SD	*t* value	*p* value
2nd year cohort (45)	10.82 ± 3.21	3.94	<0.001*
4th year cohort (45)	7.70 ± 4.01		

*$p < 0.05$ is statistically significant. SD: Standard deviation.

Table 3: Correlation between perception, knowledge, and skill scores among nursing students ($n = 90$)

Variables compared	*r* value	*p* value
Perception vs Knowledge	0.171	0.10
Perception vs Skill	0.164	0.12
Knowledge vs Skill	0.368	0.001*

*$p < 0.05$ is statistically significant.

rather, the emphasis was on the translation of theoretical understanding into practical emergency management skills.

The observed improvement in skill performance supports the educational value of simulation-based learning as a strategy for strengthening psychomotor and decision-making abilities in a controlled and safe environment. HFS enables learners to integrate assessment, prioritisation, and intervention skills in a manner that closely resembles real clinical situations. These findings are consistent with earlier reports suggesting that experiential learning approaches, when combined with structured debriefing, facilitate the application of classroom knowledge to clinical practice.[11,12]

Differences in responsiveness between student cohorts were observed, with greater skill gains noted among students in earlier stages of training. This finding may be explained by differences in learning needs and prior clinical exposure. Students with limited real-world experience may benefit more from structured simulation scenarios that provide guided practice and immediate feedback. In contrast, senior students may require more complex or interprofessional simulation experiences to demonstrate measurable gains, as suggested by previous studies.[13] These observations highlight the importance of aligning simulation complexity with learners' developmental levels rather than using uniform scenarios across all academic stages.

The significant positive correlation between knowledge and skill scores further indicates that improved theoretical understanding contributes to better clinical performance. However, the absence of a significant relationship between perception and performance outcomes suggests that positive learner perception alone may not directly influence measurable skill acquisition.[14] This underscores the need for repeated practice opportunities and deliberate feedback to ensure that favourable learning experiences translate into observable clinical competence.[15]

From a curricular perspective, the findings support the integration of structured simulation-based teaching modules early in undergraduate nursing education.[16] Early exposure may strengthen foundational emergency care skills and improve students' readiness for clinical placements.[17] As students progress academically, simulation strategies may need to evolve toward higher levels of complexity to maintain relevance and educational impact.[18] Adherence to established simulation standards, including structured pre-briefing and guided debriefing, remains essential for maximising learning outcomes.[19]

Several limitations should be considered when interpreting these findings. The quasi-experimental design without a control group limits causal inference, and the study was conducted in a single institution with a relatively small sample size. Additionally, only short-term outcomes were assessed, and long-term retention of skills was not evaluated. Future studies should incorporate control groups, multicentre designs, and longitudinal follow-up to better understand the sustained impact of simulation-based training on clinical performance.

In summary, HFS was associated with improved clinical skill performance among undergraduate nursing students, with evidence of effective knowledge-to-skill translation. These findings reinforce the role of simulation as a valuable educational tool in nursing curricula when appropriately aligned with learner needs and instructional objectives.

Educational and practice implications

This study's findings robustly advocate for the incorporation of HFS as an essential element of undergraduate nursing curricula. Simulation facilitates secure skill development, clinical reasoning, prioritisation, and collaboration without jeopardising patient safety. Adhering to the INACSL Standards of Best Practice,[19] the integration of structured pre-briefing, real-time feedback, and guided debriefing can improve both immediate and enduring learning outcomes. Nursing curricula should implement a progressive simulation framework to enhance impact, starting with fundamental emergency scenarios in the initial years and progressing to intricate, interprofessional simulations in the later years. This guarantees continuous engagement, advanced reasoning, and enhanced readiness for various clinical settings.

Limitations and future directions

The quasi-experimental pretest-posttest design without a control group limits causal inference, as observed improvements may be influenced by testing effects or concurrent learning experiences. The single institution setting, modest sample size, and short-term outcome assessment further restrict generalisability and prevent evaluation of long-term skill retention. Future studies should employ controlled or randomised designs, include multicentre samples, and incorporate longitudinal follow-up to assess sustained clinical performance and real-world transfer of simulation-acquired skills.

CONCLUSION

HFS significantly improved nursing students' emergency management competencies, particularly among 2nd year participants. The findings highlight that early exposure to simulation fosters stronger integration of knowledge, perception, and skill, ultimately enhancing clinical readiness. Continuous and progressive use of simulation throughout

nursing education can sustain learning engagement, strengthen decision-making, and build confidence—core attributes essential for safe and competent nursing practice.

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